Liquid Argon in Large Tank

--- Some Thermodynamic calculations

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November 4, 2004

Questions

- Heat leak
- Heat leak from chimney
- Convection flow
- Temperature distribution
- Force on wire
- Flow from surface downward

Liquid Argon in Big Tank

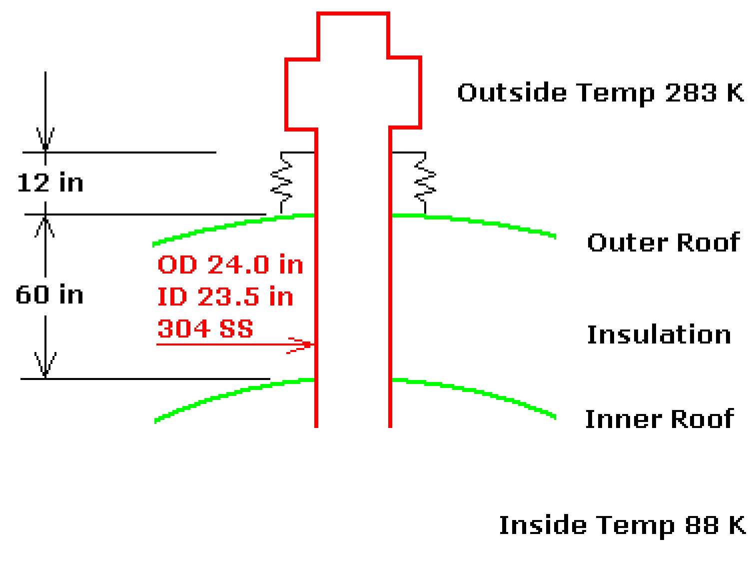
- Diameter 40 m, Height 30 m, Volume 37699 m^3.
- Heat leak cause evaporation of 0.05% per day.
- Properties of liquid argon
  - Density $\rho = 1393$ kg/m^3
  - Boiling point $T_B = 87.3$ K
  - Latent heat of evaporation $h_B = 161$ kJ/kg
  - Viscosity $\mu = 0.26e\text{-}3$ N-s/m^2
  - Thermal conductivity $k = 128$ w/m-K
  - Heat capacity $c = 1117$ J/kg-K
  - Temperature coefficient of density $\alpha = -6.19$ kg/m^3-K

Heat Leak

- Evaporation 0.05%(37699) = 18.85 m^3/day = 0.218e-3m^3/s
- (0.218e-3 m^3/s)(1393 kg/m^3)(161e3 J/kg) = 48930 w
- Assume all evaporation occurs at surface
  - Surface temperature = T_B = 87.3 K
- Assume all leak through bottom and side
  - Bottom surface 1257 m2
  - Side surface 3770 m2
  - Heat leak q = 48930/(1257+3770) = 9.734 w/m2

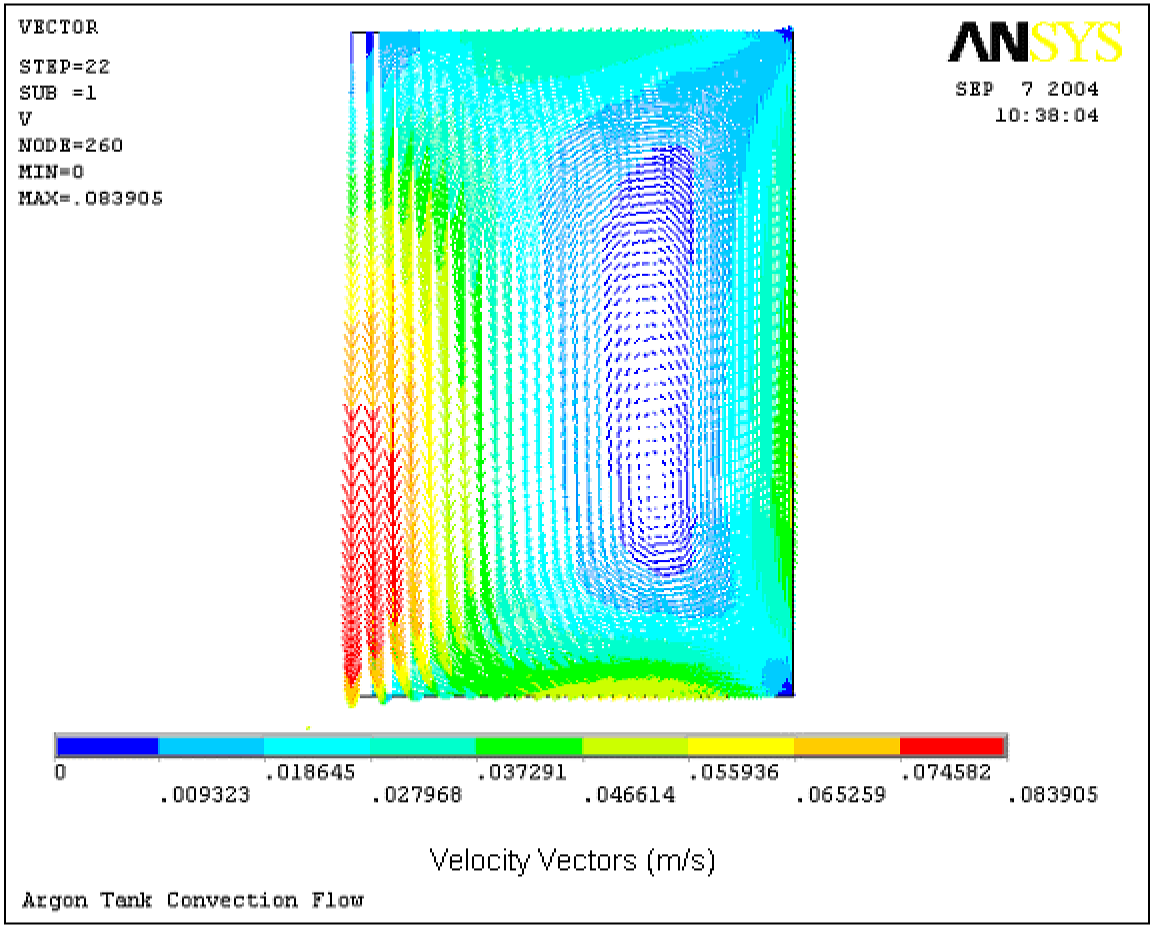
Heat Leak Through Chimney

- Neglect Convection
- Thermal conductance R=kA/L
  - **SS tube R_1 = 0.1967 W/K**
  - **Argon gas R_2 = 2.6e-3 W/K**
  - **$R_1 >> R_2$**
  - **$R_1 + R_2 = 0.1993$ W/K**
  - **$\Delta T = 283 - 88 = 195$ K**
  - **Heat leak = 39 W**
- Compare with 48930 w (0.08%)

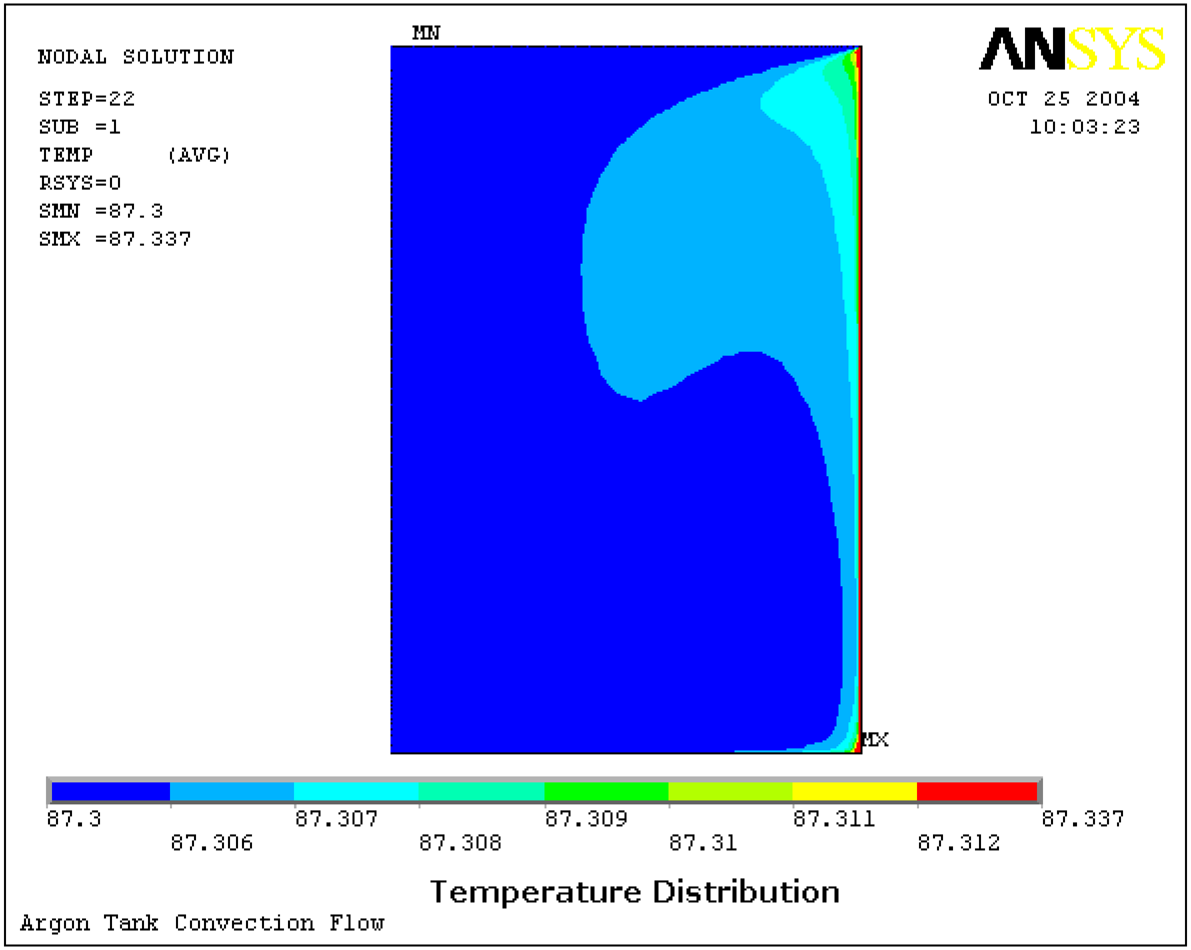


Schematic of the Chimney

Finite Element Model



Finite Element Model



From finite element model results we have following conclusions:

The convection flow is quite significant, with maximum velocity of more than 8 cm/s.

The temperature in the tank is quite uniform, with the maximum temperature difference of 0.04 K.

Dragging Force

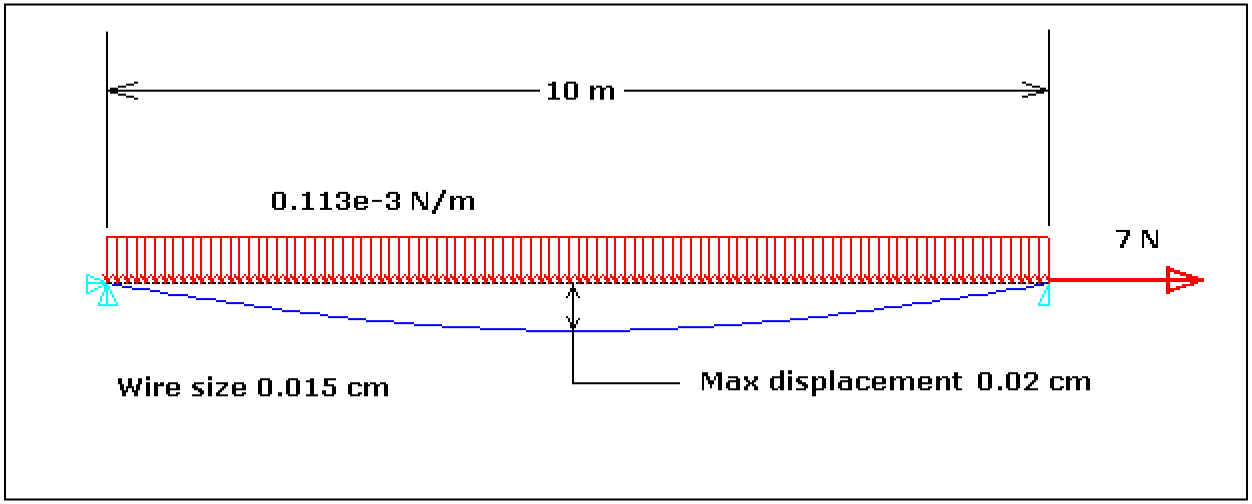
Dragging force on the wire (Viscous Flow perpendicukar to a cylinder)

$$D = 4\pi\mu U C, \qquad C = \left[\ln\left(\frac{7.4}{\mathrm{Re}}\right)\right]^{-1}, \qquad \mathrm{Re} = \frac{2a\rho U}{\mu}.$$

$$\rho = 1.393\ \mathrm{g/cm^3}, \quad \mu = 2.6e-3\ \mathrm{dyne\text{-}s/cm^2}, \quad U = 7\ \mathrm{cm/s}, \quad a = 0.015\ \mathrm{cm}.$$

$$\mathrm{Re} = 56.26, \quad C = -0.493, \quad D = -0.113\ \mathrm{dyne/cm} = \text{-}0.113\mathrm{e}\text{-}3\ \mathrm{N/m}.$$

Displacement of wire

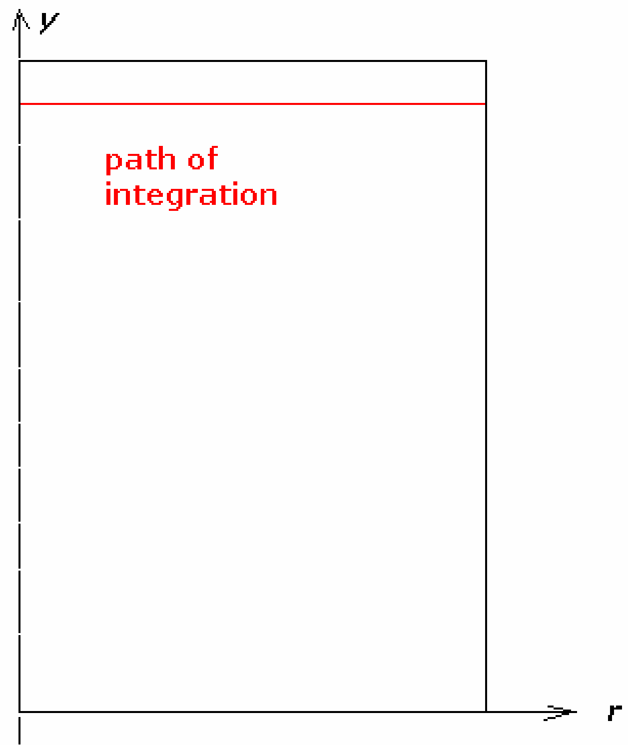


Flow from surface downward

Consider vertical flow, define

$$Q = 2\pi \int_0^r v_y \, r \, \mathrm{d}r$$

along fixed y.



Vertical Flow